A DEPARTURE IN PIPE FOUNDRY PRACTICE[1]

By Peter Gillespie[2]

That fewer examples of the craftsmanship of the ancients exist in iron than in either brass or copper is probably due less to the sequence of their discovery, than to the fact that the former metal is susceptible to corrosion while the others survive the centuries and defy decay almost indefinitely.

It is one of the most natural of conjectures that the discovery of the usefulness of iron was made by some prehistoric savage who, having built his fire on or near a mass of iron stone, afterwards observed the metallic beads produced through the deoxidizing of the ore by his fire. These beads had the constitution of wrought iron or steel or cast iron of the present day, depending on the degree to which the combination of the metal with the carbon of the fuel had taken place. Malleability, hardness and brittleness were doubtless discovered by him or his fellows and the effect of quenching the material while hot in certain cases also was probably known. In Homer's Odyssey, I–IX, the hissing of the olive-pointed stake driven by the hero Ulysses into the eye of Polyphemus is likened to the hissing of steel quenched by the smith in water for purposes of hardening:

"And as when a smith dips a great axe or adze in cold water amid loud hissing to temper it—for therefrom comes the strength of the iron—even so did his eye hiss round the stake of olive wood."

As Homer flourished nearly 1000 years before Christ, and as this art was apparently a common one in Homeric times, some idea of its antiquity may be obtained from the reference.

Cast iron was made in Sussex, England, in the fourteenth century, and in the sixteenth cannons weighing three tons were cast from it. The fuel used until that time was charcoal made from forest timber, the favored method of creating an artificial draft being by water power. Early in the seventeenth century, Dud

[1] Presented before the Philadelphia Convention, May 17, 1922.

[2] Professor of Civil Engineering, University of Toronto, Toronto, Canada.

Dudley in England produced cast iron successfully, using coke as fuel. This advancement in the art is usually attributed to the legislation of the Elizabethan period, forbidding the cutting of timber for iron making and preventing the erection of iron foundries in certain sections of that country.

While the intervening centuries have witnessed the introduction of the modern blast furnace and cupola, the use of flux, the preheating of the blast and the application of the sciences of metallurgy and chemistry generally to the production of iron and its alloys, it is also true that there has been less development in the art of producing iron castings than in that of most other engineering commodities and this notwithstanding the fact, that they enter so very largely into structures and machines of almost every kind. It is proposed here to describe briefly a comparatively recent but distinct advance in the founder's art, the making of iron pipe by the de Lavaud centrifugal process.

The problem of employing a revolving mould in the process of casting is one that for generations has appealed to the inventor, and it is indeed astonishing that developments along this line have been so long delayed. The history of early attempts to solve it is one marked mostly by failure in which the names of Eckhardt, Taylor and Wailes, Huth and others appear. No significant progress in the application of the method to commercial production in the metal industry seems to have been made until quite recently. Although it is now employed in the production of articles of non-metallic and non-ferrous composition, it is with the manufacture of cast iron bell and spigot pipe with which this article is primarily concerned.

For the manufacture of cast iron by the de Lavaud process, a plant consisting of a cupola, a revolving water-cooled moulding machine, an annealing furnace and a dipping vat is required. The molten metal is first transferred from the cupola to a tilting ladle at one end of the machine. This ladle holds slightly more iron than is required for a single pipe of the size to be cast. By an ingenious and perfectly controlled hydraulic device, this ladle can be made to discharge its contents into a cantilevered water-cooled trough which projects into the interior of the revolving mould and from the forward end of which iron is permitted to discharge in a stream lying nearly in the plane of revolution.

The machine includes an accurately made hollow cylindrical mould whose inner dimensions are identical with the outer dimensions of

the finished pipe, including the enlarged bell end. This mould is revolved on its axis by an impulse water wheel integral with it, inside a cylindrical stationary casing, the annular space between the two cylinders being filled with cooling water which is continually changing under a moderate pressure maintained at the inlet end. Escape of this water at the ends of the machine between the moving mould and the stationary casing is prevented by the use of gland-like rings somewhat similar to collar thrust bearings employed in marine work. The revolving mould is supported at two points in its length by two sets of friction rollers which have bearings on the inside of the casing and are lubricated by grease cups accessible from the outside. To shape the inside of the bell a single small core is used—the only one employed. This provides an annular shelf for the centering of the spigot and the undercut chase in the bell for the reception of caulking lead when the pipes are jointed in service. No bead is provided at the spigot end, this feature being omitted in order that the pipe may be drawn from the mould after solidification of the iron has taken place. The casing and its contained mould are made to travel back and forth on horizontal ways by means of a hydraulic cylinder installed beneath the casing.

Assume the tilting ladle filled with the necessary quantity of molten iron and the movable casing run forward so that the extremity of the cantilevered trough registers even with the remote end of the mould which is always the bell end. The turbine is started and when the mould has acquired its proper speed, the tilting ladle is tipped forward discharging its contents into the cantilevered trough. The observer at the bell end signals the first appearance of the molten metal at his end of the pipe whereupon the operator in charge of the hydraulic cylinder immediately starts the backward movement of the casing on its ways. The fluid iron is thus supplied to the mould continuously right out to the spigot end. In contact with the cool revolving mould it solidifies in a few seconds and shrinks from the mould slightly but sufficiently to be withdrawn therefrom by a special hook that engages the spigot end when the casing is again moved on its ways in the forward direction. The pipe is then passed directly to the annealing furnace in which case its residual heat is conserved or is allowed to cool in air. The normal output from a machine is fourteen 6-inch pipes per hour, the operating gang numbering seven men.

The process of annealing comes next. The furnace is oil-fired. In it, the equivalent of five 6-inch pipes may be treated simultaneously. By a mechanism, these pipes are slowly revolved as the blast plays on them so that all portions are equally heated. This prevents warping and secures uniformity in quality in all parts of the pipe. The temperature is controlled by optical pyrometers.

Class "C" pipes manufactured for waterworks service in accordance with the specifications of this Association have for 4-inch, 6-inch, and 14-inch sizes, weights of 23.3, 35.5 and 116.7 pounds per lineal foot respectively. De Lavaud pipes of the same nominal sizes have weights of 15, 24 and 62.5 pounds per lineal foot respectively.

Tests of pipe material

The metal in de Lavaud pipes is a fine grained gray iron, uniform in appearance and texture, remarkably free from blow holes and slag pockets and having a wall of thickness surprisingly uniform. From time to time the writer has conducted tests on these pipes and on samples of metal cut therefrom for the purpose of comparison with materials cut from sand mould pipes poured from the same heat. In one instance, the two materials when analyzed gave the following results:

CONSTITUENT	MACHINE MADE PIPE	SAND CAST PIPE
	per cent	*per cent*
C.	3.45	3.67
Mn.	0.49	0.61
S.	0.053	0.044
P.	0.563	0.654
Si.	2.48	2.00

The tensile strength of the machine made cast iron was 37,000 pounds per square inch; that of the sand mould iron was 16,000 pounds per square inch.

The modulus of rupture in cross-bending for the former material was 64,000 pounds per square inch; for the latter 34,000 pounds per square inch.

The resilience in inch pounds per cubic inch determined from cross-bending was 20 for the former and 10 for the latter. The modulus of elasticity determined also from cross-bending, was 15,400,000

pounds per square inch for the former and 8,600,000 pounds per square inch for the latter. Roughly, therefore, *the strength both in tension and cross-bending, the resistance to shock and the stiffness are about twice as great for machine made iron as for the sand cast product.*

In another and more recent series, the tensile strength of the machine made product averaged 40,000 pounds per square inch; that of sand cast iron, 18,000 pound per square inch. The modulus of rupture averaged 59,000 pounds per square inch for the former and 37,000 pounds per square inch for the latter, each item being the

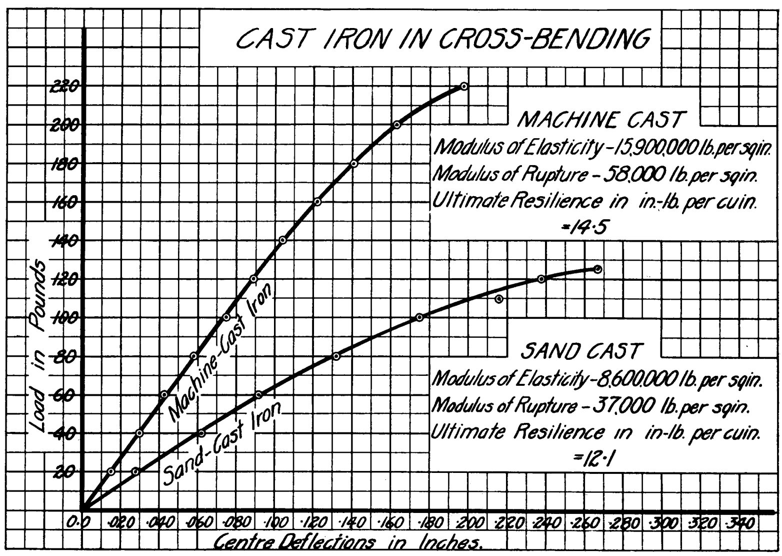


FIG. 1

average of four determinations. Two typical deflection curves, plotted from cross-bending tests, made on specimens approximately half by quarter inch cross-section and of span $11\frac{1}{2}$ inches are shown on figure 1. The disparity in the resilience factors is much less than that quoted above but there is notwithstanding substantial agreement otherwise. In interpretation of the modulus of elasticity as evaluated above, it may be said that were there two pieces of cast iron, one of each class, each 100 feet long and each subjected to a tensile stress of 10,000 pounds per square inch the stretch in the machine made pipe would be 0.75 inch while that in the sand cast

pipe would be 1.4 inches. Other things being equal, the stretch is less for the more rigid material. A 6-inch pipe tested by the writer recently sustained an internal hydrostatic pressure of 2100 pounds per square inch without failure. As the walls were 0.32 inch thick and the internal diameter was 6.25 inches, the circumferential tensile stress in the metal shell was practically 20,000 pounds per square inch. It was the intention to test this pipe to destruction, but the end gaskets gave out at the pressure indicated and the idea of testing to failure had to be abandoned.

Accurate determinations of the weight per cubic foot showed that the two materials differed but little in this respect. This weight was 433 pounds per cubic foot for each class.

CONSTITUTION OF CAST IRON

Cast iron in the molten state is a solution of carbon in iron. When cooled the carbon may be present (*a*) as precipitated graphite, in which case the iron is "gray," or (*b*) in the form of a compound of carbon and iron called cementite (Fe_3C), in which case "white" iron exists, or (*c*) and, perhaps more frequently, partly as graphite and partly as cementite. "Ferrite" is the name applied to pure iron and "pearlite" to a combination of ferrite and cementite in alternate laminae. Slow cooling tends to the production of graphitic carbon, while "chilling" produces the hard cementite characteristic of white irons. Now if chilled irons be exposed to a temperature sufficiently high and of sufficiently long duration, the carbon tends to graphitize, that is the iron tends to change from white to gray. The temperature necessary to accomplish this depends upon the composition of the iron, but must exceed 730°C. It will be obvious, then, that the constitution and properties of an iron containing, say, 3 per cent of carbon, may be quite uncertain depending upon the manner in which the carbon exists therein. It may consist of: graphite 3 per cent, and ferrite 97 per cent, in which case the iron will be gray and soft. Remembering further that iron combines with carbon to form cementite in the ratio of 14 to 1, there may also result a product of the composition, cemetite 45 per cent and ferrite 55 per cent, in which case the iron is white, hard and brittle. A portion of these two constituents would of course go to form pearlite. Again, supposing that one-third of the carbon exists in the form of cementite, there would result cementite 15 per cent, ferrite 83 per cent, and graphite 2 per cent. The first two ingredients totalling 98 per cent of the

whole, constitute a matrix of pearlite in which the flakes of graphite are interspersed and which in consequence is weakened thereby. It should be remembered that graphitic carbon, if present in large flakes, is a cause of lowered strength.

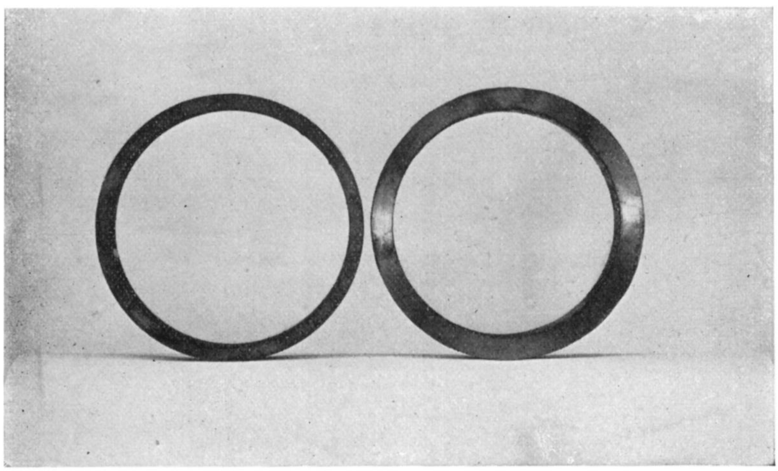


FIG. 2. WALL THICKNESSES OF MACHINE-MADE PIPE (LEFT) AND SAND MOULD PIPE (RIGHT)

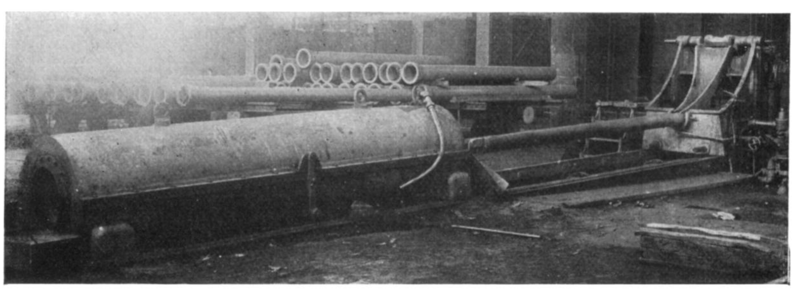


FIG. 3. MACHINE FOR MAKING PIPE

The chilling of the outer layer of metal in pipes made by the de Lavaud process results in the formation there of a thin annulus of white iron. To convert this to a gray iron, the pipes are annealed as stated above. The molecular structure after annealing is different, however, from that of sand cast iron as the accompanying photographs show. The graphite is more finely divided than in the

latter where large flakes of that material are in evidence. The explanation of the greater strength of the machine-made material probably lies in this fact.

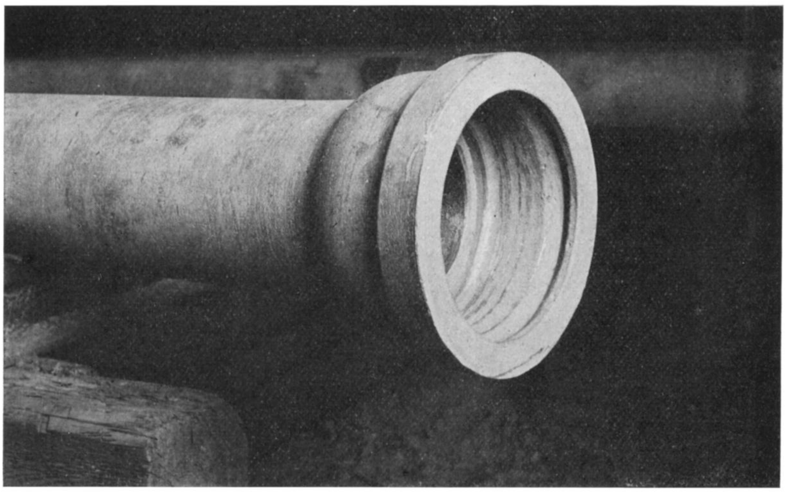


FIG. 4. BELL END OF MACHINE MADE PIPE, SHOWING SHELF FOR CENTERING SPIGOT

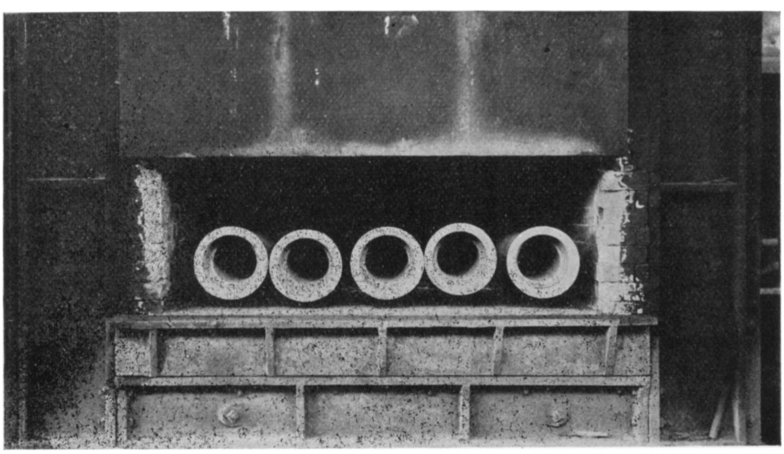
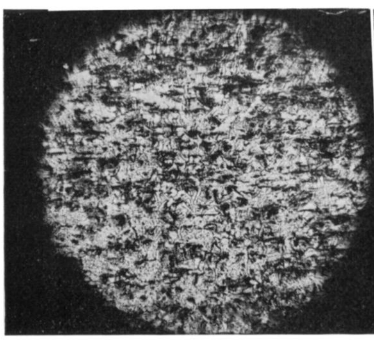


FIG. 5. MACHINE-MADE PIPE IN ANNEALING FURNACE

Further, in the fact that smooth metal rusts more slowly than rough (machine moulded pipe is unusually smooth, especially on its

outer surface), an indication as to long life may be found. Recent researches in the field of electro-chemistry have established fairly well the principle that a metal which is homogeneous in its structure and properties is not likely to develop those differences of electric potential that make for corrosion in service. May not, therefore, the homogeneous structure characteristic of de Lavaud metal be an indication also of its capacity to resist common influences tending toward corrosion?

The de Lavaud process is one that has great possibilities for usefulness and economy. To the manufacturer it means less metal, less



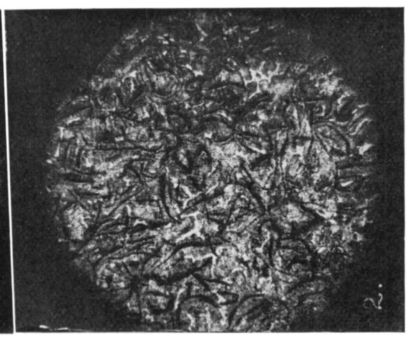


FIG. 6 FIG. 7

FIG. 6. DISTRIBUTION OF GRAPHITE IN MACHINE-MADE PIPE
FIG. 7. GRAPHITIC FLAKES IN SAND MOULD PIPE

labor, and less foundry space, since areas for storage and mixing of sand and for flasks are not required. Moreover the number of rejections at the point of inspection is remarkably low. These circumstances favor an increased output. To the shipper and the customer, the lessened weight is an important consideration. The user finds the absence of imbedded sand grains a matter of much importance when he comes to machine the metal which he finds of uniform texture, free from blow-holes, easily worked, and capable of taking a clean steel-like thread when tapped for house connections. To him also the smooth interior and greater cross-section of bore for a given outside diameter are circumstances of some account, favoring, as they do, increased carrying capacity. All in all, the development marks a significant advance in the replacement of manual labor by the machine so characteristic of the industrial achievements of the present century.